Eco. Env. & Cons. 29 (May Suppl. Issue) : 2023; pp. (S83-S92)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i03s.018

Influence of weather parameters on progress of Alternariaster leaf blight of sunflower

Venkataramanamma K.*[1], Neelima S.[2], Prabhakar K.[3], Ravi Prakash Reddy B.V.[4], Lakshmi Kalyani D.[5], Siva Rama Krishna K.[6] and Mohan Vishnu Vardhan K.[7]

Regional Agricultural Research Station, Nandyal, ANGRAU 518 502, A.P., India

(Received 23 November, 2022; Accepted 29 January, 2023)

ABSTRACT

One of the major disease in sunflower i.e., blight caused by *Alternariaster helianthi* can infect all growth stages and causes severe losses. It is seed borne pathogen and causes heavy defoliation under congenial climate and yield losses estimated from 20 to 80%. A field study was conducted on impact of weather parameters on Alternariaster leaf spot of sunflower during kharif, for four years i.e., 2013-14, 2014-15, 2015-16, 2016-17 at RARS, Nandyal with four different dates of sowing, using two cultivars KBSH-44 and morden and the disease was recorded at weekly interval. Influence of weather parameters on PDI corresponding to the same week or previous week were observed and the conditions like moderate temperatures, relative humidity (RH-I>80% and more RH-II), more rainfall and crop age have more influence on disease development. Correlation coefficient values for combined data of four years indicated that PDI was negatively correlated with T_{max}, T_{min}, rainfall and wind velocity on both cultivars and positive with RH-I and plant age. Regression equations in all the individual experimental years and in total indicated that T_{min}, T_{max}, RH-I, rainfall and age significantly influence the disease progress. Apart from these factors, dew point, spore load, sunshine hours and micro climate may also affect disease development. Hence, disease progression mainly depends on weather conditions. More AUDPC values observed in later date of sowings than early date of sowings.

Key words: *Sunflower, Weather parameters, Alternariaster, KBSH-44, Morden.*

Introduction

Sunflower is one of the major oil seed crop in India. It is cultivated in an area of 2.25 lakh ha with a production of 2.28 lakh tons and productivity of 1011 kg/ha in the year 2021-22 (Directorate of Economics and Statistics, 2022). Its production can be hampered by leaf spot and blight disease caused by *Alternariaster helianthi* which reduces seed germination and seedling survival (Udayashankar *et al.*, 2011). It can cause leaf and stem lesions, seedling blight and head rot and in severe cases total defoliation occurs. In India, the disease was first reported by Narain and Saksena (1973) and Kolte and Mukhopadhyay (1973) from Uttar Pradesh. High humidity and moderate to warm temperatures favor this disease. Yield losses of 20 to 80%, with oi1 losses of 20 to 30% have been reported from tropical and subtropical sunflower production regions (Howard and Gent, 2007). Due to the frequent occurrence of congenial climatic conditions favourable for the disease epidemics i.e., high relative humidity and temperatures between 25 ^{o}C and 30 ^{0}C leads to disease development. Information on effect of sowing dates

([1]Sr.Scientist (Pl.Path), [2]Senior Scientist (Pl.Breeding), ARS, Kadiri, [3]Scientist (Agronomy), [4]Scientist (Pl.Breeding),[5]Scientist (Agronomy), [6]Sciensit (Entomology), [7]Scientist (Pl. Breeding)

and influence of weather factors on development of disease can help in further refining disease management strategies. The rate of disease increase in fields and the cumulative amount of disease over a season (expressed as AUDPC) gives overall measures of disease progress and it was reported in relation to different diseases. It can be viewed as a grading scale in disease progress over different seasons. In this view, an experiment was conducted to know suitable date of sowing with less disease severity in kharif season, to find influence of key weather factors in disease development and also to develop forecasting models for disease prediction, thereby minimization of yield losses.

Materials and Methods

The experiment was carried out at Regional Agricultural Research Station farm, Nandyal (15°27°N and 78°28°E) of Andhra Pradesh for a period of four years from *kharif* 2013-14 to 2016-17 under All India Coordinated Research Project on sunflower scheme. The soil of the experimental field is black cotton, with pH 8.3 and EC 0.26 dS/m. The experiment was conducted in kharif season with four different dates of sowings, such as July 2nd fortnight, August 1st fortnight, August 2nd fortnight and September 1st fortnight in non replicated plots by using two susceptible cultivars such as KBSH-44 and Morden and the same obtained from Principal Investigator (Pl. Pathology) of AICRP on sunflower scheme at IIOR, Hyderabad. Plot size was maintained as 4.8x 3m^2, spacing of 60x30 cm and fertilizer schedule of 24-0-12 NPK kg/ac was followed. All agronomic practices were followed as per technical programme. Disease severity to be recorded on standard 0-9 scale from the day of disease appearance on upper, middle, lower two leaves of 15 randomly selected plants from each plot (Anonymous, 2014). Based on the intensity of the disease appearance on sunflower leaves was recorded through visual estimation by following 0-9 scale.

The details of the scale are as shown below.

0 No symptoms on the leaf
1 Small, circular, scattered brown spots covering 1% or less of the leaf area
3 Spots enlarging, dark brown in colour covering 1-10% of leaf area.
5 Spots enlarging, dark brown in colour, target like appearance covering 11-25% of leaf area
7 Spots dark brown, coalescing with target like appearance covering 26-50% of leaf area
9 Spots uniformly dark brown, coalescing covering 51% or above of leaf area.

From the above data, Percent Disease Index (PDI) was calculated (Mayee and Datar, 1986) by using the given formula:

$$\frac{\text{Sum of individual rating}}{\text{No. of leaves examined} \times \text{Maximum disease grade}} \times 100$$

PDI values along with crop age were correlated with weekly mean of weather parameters such as temperature maximum (T_{max}), temperature minimum (T_{min}), relative humidity morning (RH-I), relative humidity evening (RH-II), rainfall, wind speed etc, which were obtained from Agro meteorology department, RARS, Nandyal. The data was again subjected to step down regression by taking significant parameters into consideration and linear regression equations were developed for disease prediction.

AUDPC was computed using the formula of Wilcoxson *et al*. (1975), who quantified the AUDPC as A-value:

$$\text{AUDPC} = \sum_{i=1}^{K} ½\ 1(yi+yi\text{-}1)\ d$$

Where y_i is the disease incidence at ith day of evaluation

k is the number of successive evaluations

d is the interval between i and i-1 evaluation

Results and Discussion

During 2013, Alternariaster leaf spot disease was observed in all four dates of sowings, and more disease severity was observed on modern compared to KBSH-44. In all dates of sowings, it was observed that disease severity and spread was almost same. During this year (Table 1) disease symptoms started to appear from 27th day after sowing (vegetative stage) in fourth date of sowing to 44th day after sowing (star bud stage) in the remaining dates of sowing and progressed till harvesting depending on the prevailing weather conditions. Usually, disease progression depends on rainfall, temperature and relative humidity conditions prevailed in the corresponding and previous weeks. It was observed that disease was rapidly progressed from 36th to 38th MW (meteorological week) and 37th to 39th MW in first and 2nd date of sowings respectively compared to other weeks. In 3rd and 4th date of sowings, disease progress was rapid from the weeks of 38th to 40th weeks and 40th to 42nd weeks respectively. During these weeks, weather conditions observed that, T_{min} and T_{max} were in the range of 23.5^0 to 24.6^{0}C and 31.1^0 to 33.7^{0}C respectively, RH-I was more than e" 80% and more RH-II with rainfall in the range of 1.6 to 8.1 mm received except 39th week. In the remaining weeks disease progress was slow compared to these weeks. Crop age plays very important role in disease progression, as the age of the crop is increasing disease progression is gradual.

During the year 2014, disease pressure was less on both cultivars compared to the year 2013 and more severity was observed on morden than KBHS-44. More disease severity was observed in fourth date of sowing, as 72.68% on morden and 73.4% on KBSH-44 and less disease severity i.e., 36.2% and 43.23% observed on KBSH-44 and morden respectively in first date of sowing (Table 2). Weather conditions differed from one date of sowing to other, in fourth date of sowing, T_{min} (17.1^{0}C to 23.2^{0}C), RH-I ≥ 80% except 44th week and more amount of rainfall (0 to 15.3 mm), whereas in first date of sowing, weather factors like T_{min} (23.9^{0}C to 25^{0}C), T_{max} (30.4^0 C to 35.1^{0}C), less relative humidity (<77%) and rainfall (0 to 9.9 mm) was received. Thus more disease severity was observed in 4th date of sowing. Though, the disease was started early in all sowing conditions except first, disease progress was slow or decreasing in MW of 39 to 42, where weather conditions like T_{min} (24.1 to 25^{0}C), T_{max} (34^{0}C to 34.3^{0}C), RH-I (72.4 to 77%) and rainfall (0-1.9 mm) were observed. In fourth date of sowing, disease progression was very rapid from 43rd to 44th week due to more congenial weather conditions. As the plant is becoming old, disease also progressed and become severe at the end of crop season.

During 2015, disease pressure was observed as almost same on both the cultivars and observed more disease in first and second dates of sowings than third and fourth date of sowings (Table 3). Increase in disease pressure was observed in MW such as 37th to 40th weeks, where T_{min} (24.4^{0}C-25.1^{0}C), T_{max} (31^{0}C to 34.5^{0}C), RH-I (81.3 to 88%), rainfall (4.9 to

Table 1. Percent Disease Index (PDI) of Alternariaster leaf spot and mean weather parameters for the year 2013:

Date of Sowing	MW	PDI (%)		T_{max}	T_{min}	RH-I	RH-II	RF	WV	age
		KBSH-44	Morden	(^{o}C)	(^{o}C)	(%)	(%)	(mm)	(Km/hr)	(days)
I Dos (July 2nd FN)	35	17.28	29.63	34.0	25.1	86.1	47.2	2.4	4.4	44
	36	32.80	37.04	31.9	23.5	79.1	60.4	7.0	4.6	52
	37	48.68	52.38	31.1	24.1	86.1	61.7	8.1	2.2	59
	38	59.09	61.32	31.3	23.8	89.4	64.3	4.2	4.9	67
	39	61.32	70.37	33.7	24.6	78.6	51.6	0.0	5.2	74
	40	71.85	88.15	31.9	24.0	80.3	65.9	1.6	3.3	81
II Dos (August 1st FN)	37	22.22	27.16	31.1	24.1	86.4	61.7	8.1	2.2	37
	38	34.57	55.56	31.3	23.8	89.4	64.3	4.2	4.9	44
	39	60.45	78.23	33.7	24.6	78.6	51.6	0.0	5.2	51
	40	72.45	89.54	31.9	24.0	80.3	65.9	1.6	3.3	58
	41	82.43	91.27	32.1	23.6	82.3	61.3	3.2	4.5	65
	42	83.00	91.20	33.2	24.3	80.4	63.4	0.1	2.0	71
III Dos (August 2nd FN)	38	19.67	21.56	31.3	23.8	89.4	64.3	4.2	4.9	37
	39	34.51	36.79	33.7	24.6	78.6	51.6	0.0	5.2	44
	40	54.00	62.24	31.9	24.0	80.3	65.9	1.6	3.3	51
	41	62.24	79.00	32.1	23.6	82.3	61.3	3.2	4.5	58
	42	72.04	90.00	33.2	24.3	80.4	63.4	0.1	2.0	65
	43	80.90	95.47	28.7	23.2	91.7	80.3	17.2	3.6	71
	44	81.00	95.80	31.8	23.3	83.0	62.6	0.0	2.8	78
IV DOS (september 1st FN)	40	24.44	35.56	31.9	24.0	80.3	65.9	1.6	3.3	28
	41	46.67	60.00	32.1	23.6	82.3	61.3	3.2	4.5	35
	42	57.33	73.33	33.2	24.3	80.4	63.4	0.1	2.0	42
	43	71.95	80.95	28.7	23.2	91.7	80.3	17.2	3.6	49
	44	74.81	86.67	31.8	23.3	83.0	62	0.0	2.8	56
	45	83.12	92.01	31.4	20.8	86.7	60.2	0.0	3.4	64
	46	83.12	92.01	31.2	20.1	80.0	55.4	0.0	2.7	70

11.2 mm) in first and second dates of sowings, 46th and 47th weeks in fourth date of sowings because of T_{min} (20.7 to 22.4), RH-I (82.9– 84.6%) and rainfall (0.8 to 1.1mm). Increase in disease pressure might be due to more humidity (>80% for RH-I and >55% for RH-II) more amount of rainfall (3.8 to 20.8 mm) and also low temperature. On both cultivars, severity was increased with age. In 3rd and 4th date of sowings, disease appeared early compared to rest of dates of sowings, but disease progress is slow, due to prevalence of less humidity and less rainfall.

During 2016, disease was observed more in morden than KBSH-44 in all dates of sowings. In the first and second date of sowings, more disease severity was observed particularly from 37th to 40th MW (Table 4), where the prevailing weather factors like T_{max} (28.9⁰C to 32.2⁰C), T_{min} (23.8⁰C to 24.6⁰C), RH-I (83.9 to 89%), RH-II (59.3 to 78.9%), rainfall (1.9 to 12.6 mm) are favourable for disease development and in 3rd and 4th date of sowings, slow progress of disease, due to less amount of rainfall coupled with less humidity and temperature conditions, but disease progression was observed with plant age.

From the data of all four years, it was observed that morden cultivar is more susceptible than KBSH-44 almost in all date of sowings. Morden might be more genetically susceptible than KBSH-44. The results of same experiment, which was conducted at DOR (present IIOR), Hyderabad and AICRP on Sunflower scheme at Coimbatore centres revealed that disease severity was more on morden than KBHS-44 during the experimental year 2013 (Anonymous, 2013-14). It is well known that every pathogen requires specific weather conditions for its occurrence, development and spread. Disease severity and spread mainly depends on different meteorological parameters apart from crop age. Santha lakshmi Prasad *et al*. (2017) suggested that disease generally starts at 35-40 days after sowing, if weather conditions are conducive, it spreads quickly

Table 2. Percent Disease Index (PDI) of Alternariaster leaf spot and mean weather parameters for the year 2014:

Date of sowing	MW	PDI (%)		T_{max}	T_{min}	RH-I	RH-II	RF	WV	age
		KBSH-44	Morden	(°C)	(°C)	(%)	(%)	(mm)	(Km/hr)	(days)
I DOS (July 2nd FN)	37	12.83	10.61	33.0	23.9	38.0	33.4	9.9	6.4	48
	38	29.98	26.17	30.4	24.1	87.7	66.7	7.0	3.1	55
	39	30.01	32.26	34.3	25.0	74.4	59.0	1.5	2.6	62
	40	32.91	34.37	35.1	24.2	76.0	54.0	1.7	2.9	69
	41	33.73	39.47	34.2	24.4	72.4	51.3	0.0	2.6	76
	42	36.20	43.23	34.0	24.1	77.0	64.1	1.9	3.3	83
II DOS (August 1st FN)	37	04.69	05.67	33.0	23.9	38.0	33.4	9.9	6.4	31
	38	11.41	11.72	30.4	24.1	87.7	66.7	7.0	3.1	37
	39	30.45	29.62	34.3	25.0	74.4	59.0	1.5	2.6	45
	40	31.34	32.54	35.1	24.2	76.0	54.0	1.7	2.9	52
	41	31.34	32.54	34.2	24.4	72.4	51.3	0.0	2.6	60
	42	31.34	32.54	34.0	24.1	77.0	64.1	1.9	3.3	67
	43	36.75	39.78	31.9	23.2	84.9	64.0	15.3	3.7	74
	44	48.67	57.65	31.3	20.7	75.0	61.6	0.0	2.4	80
III DOS (August 2nd FN)	39	19.75	17.28	34.3	25.0	74.4	59.0	1.5	2.6	24
	40	14.40	10.28	35.1	24.2	76.0	54.0	1.7	2.9	31
	41	06.17	07.81	34.2	24.4	72.4	51.3	0.0	2.6	41
	42	09.43	09.54	34.0	24.1	77.0	64.1	1.9	3.3	48
	43	10.86	23.76	31.9	23.2	84.9	64.0	15.3	3.7	55
	44	35.67	54.07	31.3	20.7	75.0	61.6	0.0	2.4	61
	45	49.56	61.40	31.2	20.3	80.7	60.4	0.0	2.6	67
	46	51.20	62.40	29.8	21.4	87.6	70.0	1.3	3.2	74
IV DOS (September 1st FN)	43	07.14	09.13	31.9	23.2	84.9	64.0	15.3	3.7	31
	44	48.80	46.09	31.3	20.7	75.0	61.6	0.0	2.4	37
	45	54.36	51.54	31.2	20.3	80.7	60.4	0.0	2.6	43
	46	59.87	55.79	29.8	21.4	87.6	70.0	1.3	3.2	51
	47	67.90	70.30	30.9	19.7	85.0	61.6	0.0	2.6	58
	48	73.40	72.68	29.9	17.1	81.3	56.3	0.0	2.6	64
	49	73.80	72.90	30.8	18.8	76.6	58.4	0.0	3.5	71

to upper leaves and covers the entire leaf causing blight symptoms. Gud *et al*. (2007) suggested that rains coupled with high humidity above 80% and temperature in the range of 21 to 32^{0}C favours the primary infection of Alternaria leaf spot in safflower crop. In the present experiment also, weather conditions like high humidity of above 80%, moderate temperatures (both T_{min} and T_{max}) and rainfall distribution during the experimental period might have favoured disease development. These conditions favoured conidial germination, multiplication, thus aid in disease development. Conidial germination occurs best at temperatures less than 26^{0}C and require a minimum of 4 hours of leaf wetness for sporulation (Udayashankar *et al*., 2012). The pathogen is dispersed, spread through windblown or water splashed onto lower leaves of sunflower. Disease progression majorly depends on the duration of leaf wetness following initial infection, as it was observed that germination of new spores can occur within days. Similar disease progression was observed in the experiment conducted at DOR, Hyderabad under high humid conditions (>80%) and temperature (20.1^{0}C to 24.1^{0}C), T_{max} (22.5^{0}C to 32.5^{0}C) with dew point (Anonymous, 2013-14). In vegetative stage also, hot weather and frequent rain can accelerate the disease intensity. Usually, disease spreads more from flowering stage (50-55 DAS) and reached maximum towards the maturity of the crop (75-80 DAS), even though the vertical spread of the disease is less when the RH-I values dropped below congenial without rainfall. In the present experiment, same weather conditions prevailed in different years provoked the disease severity in sunflower crop. Santha lakshmi Prasad *et al*. (2017) conducted an experiment to find out resistant sources for Alternariaster leaf spot disease in field and found less disease in the experimental period of 3 years (2003-04, 2005-06, 2008-09) due to low rainfall with fewer rainy days per week and low relative humidity and more disease during 2004-05, 2006-07, 2007-08 and 2009-10, which was favoured by high rainfall, rainy days of 2 to 5 per week with high relative humidity of 89-94% and more spore load during V5

Table 3. Percent Disease Index (PDI) of Alternariaster leaf spot and mean weather parameters for the year 2015:

Date of sowing	MW	PDI (%)		T_{max}	T_{min}	RH-I	RH-II	RF	WV	Age
		KBSH-44	Morden	(°C)	(°C)	(%)	(%)	(mm)	(km/hr)	(days)
I DOS(July 2nd FN)	36	07.35	14.67	36.4	24.8	76.0	53.4	03.7	6.5	53
	37	18.57	22.52	31.0	24.1	88.0	75.7	20.8	5.6	59
	38	38.57	36.51	32.9	25.1	80.4	58.4	03.8	5.2	66
	39	48.39	56.91	34.8	25.1	81.3	64.6	11.2	4.1	73
	40	74.72	73.66	32.3	24.4	88.0	71.0	04.9	3.1	80
	41	75.30	73.66	34.5	24.8	85.1	55.1	0.0	3.7	85
II DOS(August 1st FN)	37	11.32	12.56	31.0	24.1	88.0	75.7	20.8	5.6	56
	38	21.39	21.39	32.9	25.1	80.4	58.4	03.8	5.2	63
	39	28.39	34.97	34.8	25.1	81.3	64.6	11.2	4.1	70
	40	52.26	60.49	32.3	24.4	88.0	71.0	04.9	3.1	77
	41	72.01	72.83	34.5	24.8	85.6	55.1	0.0	3.7	84
III DOS(August 2nd FN)	38	14.40	20.16	32.9	25.1	80.4	58.4	03.8	5.2	37
	39	18.93	25.92	34.8	25.1	81.3	64.6	11.2	4.1	44
	40	32.92	36.62	32.3	24.4	88.0	71.0	04.9	3.1	51
	41	37.03	36.62	34.5	24.8	85.6	55.1	0.0	3.7	58
	42	37.57	36.84	35.5	24.1	73.0	49.1	0.0	3.6	65
	43	37.64	37.44	35.2	21.6	72.9	47.7	0.0	4.0	72
	44	41.97	47.32	34.1	23.9	79.6	57.9	0.0	4.1	79
	45	58.02	60.50	32.6	23.3	74.1	55.1	0.5	4.5	85
IV DOS(September 1st FN)	41	11.11	07.81	34.5	24.8	85.6	55.1	0.0	3.7	35
	42	16.04	11.11	35.5	24.1	73.0	49.1	0.0	3.6	42
	43	18.93	16.87	35.2	21.6	72.9	47.7	0.0	4.0	49
	44	18.50	13.58	34.1	23.9	79.6	57.9	0.0	4.1	56
	45	23.86	15.22	32.6	23.3	74.1	55.1	0.5	4.5	63
	46	32.09	34.15	30.4	20.7	84.6	60.1	1.1	3.5	70
	47	56.37	57.20	30.4	22.4	82.9	65.7	0.8	4.6	77

vegetative stage to R1 reproductive stage of the crop. Hence, higher rainfall and higher humidity that prevailed during kharif season seems to be favourable for Alternariaster leaf blight disease development.

Correlation: PDI values obtained from the experiment in different years were correlated with corresponding weather parameters prevailed in the same week along with the age of crop. The correlation coefficients were presented in the following table (Table 5).

Negative correlation was found between PDI and T_{max} for the years 2013, 2014 and significant only with KBSH-44 (-0.44) in 2014, but positive, non significant correlation was observed in the years 2015 and 2016. Negative correlation was found between PDI and T_{min} in all the experimental years and significant for the years 2013 (-0.48 and -0.44 on KBSH-44 and morden respectively) and 2014 (-0.69 and -0.49 on KBSH-44 and morden respectively).

Regarding relative humidity, significant positive correlation was found between PDI and RH-I in the experimental year 2014 (0.4 and 0.41 on KBSH-44 and morden respectively) and non significant in 2013 and 2015, whereas in the year 2016 non significant negative correlation was observed. Significant positive correlation was found between PDI and RH-II (0.4 on morden) in the year 2014, and non significant negative correlation was observed in the years 2015 and 2016. PDI was negatively correlated with rainfall and significant in the years 2014 and 2016 on both cultivars. Wind velocity in all the experimental years is negatively correlated on both cultivars and it is significant only in the year 2016.

The age of the crop played a crucial role in the disease development and spread during the crop growth period. As the age of the plant is advanced, the percent leaf area showing symptoms linearly

Table 4. Percent Disease Index (PDI) of Alternariaster leaf spot and mean weather parameters for the year 2016:

Date of sowing	MW	PDI (%)		T_{Max} (°C)	T_{min} (°C)	RH-I (%)	RH-II (%)	RF (mm)	WV (km/hr)	Age (days)
		KBSH-44	Morden							
I DOS (July 2nd FN)	35	2.12	03.12	31.9	24.8	84.1	62.9	29.5	5.3	41
	36	7.40	23.74	32.4	25.0	74.4	50.3	0.00	6.5	48
	37	08.81	37.44	28.9	23.9	86.7	77.0	12.6	6.1	54
	38	28.34	53.55	29.7	23.8	87.1	73.1	10.2	8	60
	39	45.67	79.42	30.2	24.6	89.0	78.9	1.90	4.3	66
	40	53.50	80.50	32.2	24.6	83.9	59.3	1.90	4.4	72
II DOS (August 1st FN)	35	0.30	0.45	31.9	24.8	84.1	62.9	29.5	5.3	25
	36	02.46	04.11	32.4	25.0	74.4	50.3	0.00	6.5	32
	37	08.23	14.81	28.9	23.9	86.7	77.0	12.6	6.1	39
	38	26.52	27.80	29.7	23.8	87.1	73.1	10.2	8	46
	39	39.91	40.32	30.2	24.6	89.0	78.9	1.90	4.3	53
	40	53.90	72.83	32.2	24.6	83.9	59.3	1.90	4.4	60
	41	55.10	76.13	33.2	24.1	80.4	54.4	0.50	3.9	68
	42	56.00	77.05	33.8	21.6	71.3	40.6	0.00	2.7	74
III DOS (August 2nd FN)	39	33.33	47.32	30.2	24.6	89.0	78.9	1.90	4.3	21
	40	46.90	53.90	32.2	24.6	83.9	59.3	1.90	4.4	29
	41	34.56	37.03	33.2	24.1	80.4	54.4	0.50	3.9	36
	42	35.50	39.05	33.8	21.6	71.3	40.6	0.00	2.7	43
	43	36.30	42.34	33.3	21.2	75.4	38.7	0.00	2.8	50
	44	48.97	51.31	33.4	23.9	79.6	53.7	0.00	2.9	57
	45	52.00	56.95	33.1	19.3	64.6	40.0	0.00	3.3	64
	46	57.75	63.65	32.6	22.6	80.7	60.6	0.00	3.4	71
IV DOS (September 1st FN)	40	26.74	24.27	32.2	24.6	83.9	59.3	1.90	4.4	21
	41	26.10	24.63	33.2	24.1	80.4	54.4	0.50	3.9	28
	42	26.30	26.70	33.8	21.6	71.3	40.6	0.00	2.7	35
	43	27.40	29.40	33.3	21.2	75.4	38.7	0.00	2.8	42
	44	29.62	34.97	33.4	23.9	79.6	53.7	0.00	2.9	49
	45	38.72	43.78	33.1	19.3	64.6	40.0	0.00	3.3	56
	46	42.60	53.60	32.6	22.6	80.7	60.6	0.00	3.4	63
	47	46.50	54.92	31.6	17.9	78.3	50.6	0.00	2.1	71

increased for most of the times. PDI values were highly significant with plant age positively in all the experimental years. The correlation coefficient values between PDI and crop age on KBSH-44 was 0.74, 0.58, 0.88 and 0.74 respectively in the experimental years of 2013, 2014, 2015 and 2016 respectively. These values are 0.68, 0.67, 0.88 and 0.61 on morden respectively for all the consecutive experimental years. These results are in conformity with Suresh *et al*. (2012) who reported that safflower plants were susceptible to *Alternaria carthami* at all growth stages, but susceptibility increased as the plants matured. Similar reports in tomato (Vloutoglou and Kalogerakis, 2000) was also observed. Kong *et al*. (1995) reported that sunflower plants are more susceptible when leaves become older and more vulnerable stage is anthesis for infection, when all the nutrients are mobilized for seed and oil production, withering of leaf at this stage can cause upto 85% of yield losses.

Correlation studies of four years combined data revealed that PDI values were negatively correlated with weather parameters such as T_{max}, T_{min}, rainfall and wind velocity on both cultivars and found positive with RH-I, RH-II and plant age. PDI values were significantly negatively correlated with T_{min} (-0.31), rainfall (-0.32) and wind velocity (-0.28) on KBSH-44 and positively correlated with RH-I (0.2) and crop age (0.61). On morden cultivar also, PDI values were negatively correlated with T_{min} (-0.23), rainfall (-0.29), wind velocity (-0.35) and positive correlation with RH-I (0.23) and crop age (0.59). These results are in conformity with Amaresh *et al*. (2003) who has conducted an experiment for two years (1998-99 and 1999-2000) on sunflower crop and observed that negative significant correlation between PDI and temperature maximum, while positive correlation with mean minimum temperature (0.65 & 0.73) mean morning relative humidity (0.94 & 0.85), mean after noon relative humidity (0.96 & 0.97) and rainfall (0.86 & 0.67). In the present experiment also, similar results were found but negative correlation with rainfall was observed, this might be due to occurrence and distribution of rainfall irregularly. Same experiment was also conducted at AICRP on Sunflower centre, Coimbatore and DOR, Hyderabad during 2013-14, mentioned that minimum temperature, relative humidity,

Table 5. Correlation coefficient values for Alternariaster leaf spot (PDI) in sunflower:

Weather parameters	2013		2014		2015		2016	
	KBSH-44	Morden	KBSH-44	Morden	KBSH-44	Morden	KBSH-44	Morden
			PDI values					
T_{max}	-0.24	-0.16	*-0.44	-0.29	0.03	0.03	0.13	0.32
T_{min}	*-0.48	*-0.44	*-0.69	*-0.49	-0.15	-0.14	-0.26	-0.34
RH-I	0.07	0.02	*0.4	*0.41	0.03	0.03	-0.08	-0.14
RH-II	0.36	0.33	0.37	*0.40	-0.25	-0.25	-0.06	-0.18
RF	-0.06	-0.12	*-0.50	*-0.47	-0.24	-0.25	*-0.50	*-0.60
WV	-0.24	-0.20	-0.43	-0.41	-0.43	-0.46	*-0.40	*-0.64
Pl.age	*0.74	*0.68	0.58	0.67	0.88	0.88	*0.74	*0.61

*indicates significant at 5% level of significance.

Table 6. Regression equations for *Alternariaster* leaf spot of sunflower for KBSH-44 and morden cultivars in the experimental period

Experimental year	KBSH-44	R^2 value
2013	PDI= 47.6-3.66T_{min}+0.73RH-II+0.95 age	0.71
2014	PDI= 157.73-6.1T_{min}-1.07 RF+0.33 age	0.79
2015	PDI= -132.6+2.4T_{min} +0.31RH-I+1.3 age	0.81
2016	PDI= -245.16+6.1T_{max}-5.5T_{min}+2.39RH-I-0.99RF+0.003 age	0.72
Experimental year	Morden	R^2 value
2013	PDI= 60.08-3.54T_{min}+0.69RH-II+0.93 age	0.70
2014	PDI= 156.74-6.44T_{min}-0.9RF+0.53 age	0.88
2015	PDI= -140.76+2.7T_{min}+0.3RH1+1.34 age	0.84
2016	PDI= -78.2+0.89RH-I-1.1RF+1.05 age	0.68

spore load and dew point have more impact on disease development and they considered dew point for correlation studies instead of rainfall. Similarly Suresh *et al*. (2013) suggested that PDI of *Alternaria carthami* was progressed at a linear rate throughout the plant growth and negatively correlated with maximum temperature, relative humidity at morning and evening and positively correlated with minimum temperature and age of the crop. In the present experiment, negative correlation was observed with T_{min}, it might be due to the variations in temperature.

Regression studies: For disease prediction, linear regression models were developed. The above data was subjected to step down regression after eliminating the non significant factors and the following equations were developed year wise for both cultivars as shown in table 6. Regression equations were also developed for the combined data of four years for each cultivar separately by following step wise regression to predict the impact of weather conditions on Alternariaster leaf spot disease severity.

From the regression equations of different years it is well known that T_{min} and age had more impact on disease development in almost all the experimental years and other parameters also have considerable impact on disease progress. From the above regression equations, R^2 values represents percentage of prediction for disease forecasting. From the above table, it is known that prediction percentage ranged from 71% to 81% for KBSH-44 and 68% to 88% for morden cultivar in different years in the given weather conditions.

From the above table, it is known that regression equations were developed for both cultivars from the combined data of all experimental years and R^2 values represents 57% and 54% of disease prediction only on KBSH-44 and morden respectively. Weather parameters i.e., T_{max}, T_{min}, RH-I, rainfall and age were influenced the disease progress for both cultivars under regression models. So apart from these weather parameters, some other factors like spore load of Alternariaster, leaf wetness duration, dew fall, sunshine hours and the factors of micro climate influence the disease development. Venkataramana *et al*. (1995) suggested that temperature in the range of 25 ^{0}C-27 ^{0}C with at least 12 hours of wet foliage helps to spread rapidly during the rainy season. The rainfall along with heavy dew deposition provided wetness on leaves for about 14-15 h day. The results of present experiment is in accordance with the same experiment conducted at DOR, Hyderabad in the year 2013, and they suggested that spore load, dew point, relative humidity and minimum temperature were the most influencing weather parameters for disease severity (Anonymous, 2014) and the regression equation was -1.87T_{max}+0.64RH1-0.28RH2-1.03 dew point. Similarly, maximum temperature, relative humidity and dew point were the weather parameters influenced the disease severity at Coimbatore centre (Anonymous, 2015). To get more precise R^2 values, we have to consider the other factors as other centres mentioned. Santha lakshmi Prasad *et al*., (2017) stated that cloudy weather, high humidity and drizzling rains can result in severe outbreak and spread of Alternariaster leaf spot in sunflower crop. Hence, in the coming years of experimentation, dew point, spore load, micro climate parameters can be taken into consideration.

Multiple linear regression equations for all the experimental years:

Cultivar	Regression equations	R^2
KBSH-44	152.11+0.6 T_{min} -5.3T_{max}+0.47 RH-I - 1.22 RF+0.8 age	0.57
Morden	131.37-4.7T_{max}+0.53RH-I-1.1RF+ 0.82 age	0.54

Table 7. AUDPC values (A-value)

Date of sowing	KBSH-44				Morden			
	Experimental years				Experimental years			
	2013	2014	2015	2016	2013	2014	2015	2016
I DOS (July I FN)	1786	1103	1576	834	2064	1151	1172	1662
II DOS (August I FN)	2195	1412	1045	1501	2712	1493	1161	1925
III DOS (August II FN)	2547	1200	1746	2215	3031	1507	1898	2518
IV DOS (September I FN)	2800	2437	845	2778	3321	2394	891	1854

AUDPC: AUDPC (A-value) for percent disease Index (PDI) of Alternaria leaf blight of sunflower for both cultivars in different dates of sowing in experimental years was presented in the below table.

Highest A-value was observed in fourth date of sowing for KBSH-44 in the experimental years i.e., 2013, 2014, 2016 and in 2015, highest in third date of sowing. For morden cultivar, highest AUDPC value was found in fourth date of sowing for the years 2013, 2014 and in third date of sowing for the years 2015 and 2016. In general late kharif conditions favourable for disease development. In the present research also, the A-values of late kharif season shown more amount of disease. The AUDPC value depends on the accumulation factor to attain a higher number, for this vulnerable phenological stage of crop, weather and pathogen inoculum is required to interact for a long time. Similarly Leite *et al*. (2006) conducted an experiment on Alternaria leaf blight of sunflower in Brazil for three years (1997-98, 1998-99 and 1999-2000) and concluded that the highest severity of AUDPC was observed in plants sown in December of the four growing seasons i.e., October, November, December and January and AUDPC was zero, as there is no disease in October and November sown crops and less AUDPC was observed in January sown crop. In the present experiment, more AUDPC was observed in late sown crop for majority times.

Conclusion

It was concluded that, the disease progression of Alternariaster leaf spot depends on whether factors and crop age. From the data of four experimental years, it is known that T_{min}, T_{max}, RH-I, rainfall and crop age have more influence on Alternariaster leaf spot disease. For accurate prediction, other parameters like spore load, dew point, sunshine hours and micro climatic factors may be considered. More AUDPC values observed in late sown conditions than early date of sowings.

Acknowledgements

Authors are thankful to Principal Scientist (Pl.Path), AICRP on Sunflower, IIOR, Hyderabad for giving guidelines of the work.

Conflict of Interest: Authors have no conflict of interest on publication of this research article.

References

Amaresh, V. S., Naragund, V. B., Anahosur, K. H., Kulkarni, S. and Patil, B.V. 2003. Influence of sowing dates and weather factors on development of Alternaria leaf blight of sunflower. *Karnataka Journal of Agricultural Sciences.* 16 : 68-71.

Anonymous, 2014. Annual report of AICRP on sunflower, 2013-14. Directorate of Oilseeds research (ICAR), Hyderabad. Pp.228-231.

Anonymous, 2014. DOR technical program and guidelines for implementation for 2014-15. AICRP on Sunflower, Directorate of oilseeds Research. Hyderabad. Pp.25-32.

Anonymous, 2015. Annual report of AICRP on Sunflower, 2014-15, Directorate of Oil seeds Research (ICAR), Hyderabad. Pp. 331-333.

Balasubramaniam, N. and Kolte, S.J. 1980. Effect of Alternaria blight on yield components, oil content and seed quality of sunflower. *Indian Jl. of Agricultural Sciences*. 50 : 701-706.

Gud, M. A., Murumkar, D. R., Shinde, S. K. and Kadam, J. R. 2007. Correlation of weather parameters with development of leaf spot of safflower caused by *Alternaria carthami*. *Proceedings of 7th International Safflower Conference, Wagga wagga, Australia.*

Howard, F.S. and Gent, D.H. 2007. Sunflower Alternaria leaf spot. *High Plains IPM Guide*, a cooperative effort of the University of Wyoming, University of Nebraska, Colorado State University and Montana State University.

Kolte, M. and Mukhopadhyay. H.S. 1973. Location of *Alternaria* spp. in sunflower seeds, *Plant Disease Research*. 5: 203-204.

Kong, G.A., Kochman, J.K. and Brown, J.F. 1995. A greenhouse assay for screening sunflower in resistance to *Alternaria helinathi*. *Annals of Applied Biology*. 127: 463-478.

Leite, R.M.V.B.C., Amorim, L. and Bergamin, Filho. A. 2006. Relationships of disease and leaf area variables with yield in the *Alternaria helianthi* –sunflower pathosystem. *Plant Pathology.* 55 : 73–81.

Mayee, C. D. and Datar, V. V. 1986. Diseases of safflower, Phytopathometry, a technical bulletin published by Marathwada Agriculture University, Parbhani, Maharashtra State, India. Pp: 100-104.

Narain, U. and Saksena, S.W. 1973. Occurence of Alternaria leaf spot on sunflowcr in India. *Indian Journal of Mycology and Plant Pathology*. 3: 115116.

Santha Lakshmi Prasad, M., Sujatha, M., Alivelu, K. and Sujatha, K. 2017. Sources of resistance to Alternariaster leaf blight in sunflower pre-breeding lines derived from inter specific crosses and wild Helianthus species. *Crop Protection*. 92 : 70-78.

Suresh, M., Padmavathi, P., Varma, N.R.G. and Jagadeeshwar, R. 2013. Effect of weather and growth stage of crop on *Alternaria* leaf spot development and progress in safflower (*Carthamus tinctorius* L.). *Journal of Agrometeorology.* 15 (Special Issue-II) : 135-139.

Suresh, M., Kishore Varma, P., Sudhakar, C., Sameer kumar, C. V. and Vishnu vardhan Reddy, A. 2012. Weather based fore-warning model for *Alternaria* leaf spot of safflower in southern telangana zone of Andhra Pradesh. *Journal of Oil Seeds Research.* 29: 354-359.

Udayashankar, A.C., Nayaka, S.C., Niranjana, S.R. and Prakash, H.S. 2011. Comparative efficacy of strobilurin fungicides against leaf spot and blight disease of sunflower. *Journal of Mycology and Plant Pathology*. 41 : 11-19.

Udayashankar, A. C., Chandra nayaka, S., Archana, B., Anjana, G., Niranjana, S.R., Mortensen, C.N., Lund Ole, S. and Prakash, H.S. 2012. Specific PCR based detection of *Alternaria helianthi*: the cause of blight and leaf spot in sunflower. *Archieves of Microbiology*. 194(11) : 923-932.

Vloutoglou, I. and Kalogerakis, S. N. 2000. Effects of inoculum concentration, wetness duration and plant age on development of early blight (*Alternaria solani*) and shedding of leaves in tomato plants. *Plant Pathology*. 49: 339-345.

Wilcoxson, R.D., Skovmand, B. and Atif, A.H. 1975. Evaluation of wheat cultivars for their ability to retard development of stem rust. *Annals of Applied Biology*. 80: 275–281.

Venkataramana, Nagaraju, Jagadessh, G.V. and Gowda, J. 1995. Severity of rust and Alternaria leaf spot in relation to in different sowing dates in parental lines of sunflower hybrids. *Journal of Oilseeds Research*. 12: 146-148.